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ENVIRONMENTAL STEWARDSHIP AND SUSTAINABILITY

Water Cooled Ultra Low Freezer
Performance and Energy Use

Thermo Fisher
Forma 900 Series, Model 8606

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Product Website: https://fscimage.fishersci.com/images/D13015~.pdf

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Gratitude

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Introduction

The energy intensity of laboratories has come into focus over recent years, and Labs21 has provided a website to publish this data. As well, building designers are looking for new ways to reduce building plug load and cooling from reject heat. The energy consumption of water cooled freezers is lower than air cooled units, and reject heat is shed into process cooling loops.

During September, 2011 staff and students from the office of Environmental Stewardship and Sustainability tested three water cooled, ultra low freezers (ULF, Tables 1 and 2). The manufacturers kindly shipped, helped install the freezers and advised this project. Without their enthusiastic participation it could not have occurred and we are very grateful. The results from the Thermo freezer testing are presented here.

Distributor	**Thermo Fisher**
Manufacturer	**Forma**
Model	8606
Face Width (")	41
Door Swing Min. (")	5
Cubic Feet	23
2" Boxes	400
Boxes/Linear Foot	104

Table 1. Ultra Low Freezer dimensions and capacities.

Distributor	**Thermo Fisher**
Manufacturer	**Forma**
Heat Exchangers	1
Water flow (lpm)	12
Water Delta T (°C)	1
Outer Door Hinge	2 ea Barrel, 30 cm
Door Swing	180°
Outer Door	4.5"
Latch	Cam lock, manual
Gaskets	On frame, 1 closed 2 feathers
Inner Doors	Sheet metal, slide knob
Vacuum Relief	Door, heated
Noise	62 dBA

Table 2. Freezer Construction and Doors. Water flow was measured when compressors were on. The Forma has very heavy duty hinges and gaskets mounted on cabinet that may be less likely to be scraped.

Testing methods

Energy

We used Elite Pro energy meters on loan to UC Davis from the Pacific Gas and Electric Tool Lending Library, set up with 15 Amp current transducers (CT's). Split cord pigtails provided single conductors for CT placement, or CT's were placed over single conductors inside the mechanical cabinet. All three freezer amperages were measured simultaneously to obtain Volt-Amp values. Power factor was measured individually on each freezer by attaching voltage clips in a bare wire outlet box before energizing and then insulated, thus avoiding live connection hazards. We multiplied Volt-Amps by the power factors to calculate Watts during subsequent tests. Freezers were allowed to stabilize at each temperature for 6 –10 hours, then energy measurements were logged either at 1 minute or 5 minute intervals and averaged over at least 8 hours. Freezers were empty during all tests.

Temperature

On the recommendation of cryo-temperature experts in the UC Davis Physics Department, we selected type J thermocouple (TC) wire for temperature sensing. We cut and welded 13 TC's at either 3 or 5 meters, and attached them to type J plugs. They were inter-calibrated for precision in a methanol bath with dry ice chunks and stirring. Three TC's were measured during both calibration sessions and averaged. Offsets from these averages were calculated for each TC and were applied to temperature readings, (Appendix B).

Up to eight TC's were logged simultaneously using an Omega TC-08 panel. Two TC's were placed in each ULF, one next to the installed temperature probe, and one in the geometric center of the cabinet, about 4 cm above the shelf. Intake air temperature was logged on the intake grill. Occasional room temperature measurements were made with an infrared thermometer, and room temperature was 21.4 +- 0.3 C.

Results

Temperature Characteristics

The purpose of this test was not detailed assessment of spatial and temporal uniformity. Some data was collected from the two TC's in the middle of the freezer and next to the sensor, (Table 3). At warmer temperatures the middle of the freezers were generally colder that at the sensors, which generally were near the bottom of the freezers. Further testing of temperature characteristics will be performed on loaded and unloaded air cooled freezers.

	Forma
Mean	-79.0
Max-Min	1.6
Measured - Set Point	1.0
Sensor - Middle	-0.1

Table 3. Temperature values over time and uniformity in the cabinet, (set point -80 degrees). Complete data available at -60 - -86°C in the appendix.

Energy Consumption

The Forma freezer consumed about 19 kWh/d, (Table 4). The energy intensity per box and cubic foot are also listed.

	Forma
Energy Use kWh/d	18.6
Power Factor	0.95
Energy Intensity (W/CF)	33.7
Energy Intensity (W/Box)	1.94
Electricity Cost/y (8.5 c/kWh)	$ 577
Electricity Cost/Box/y	$ 1.44

Table 4. Energy consumption and intensity at the set point -80 °C.

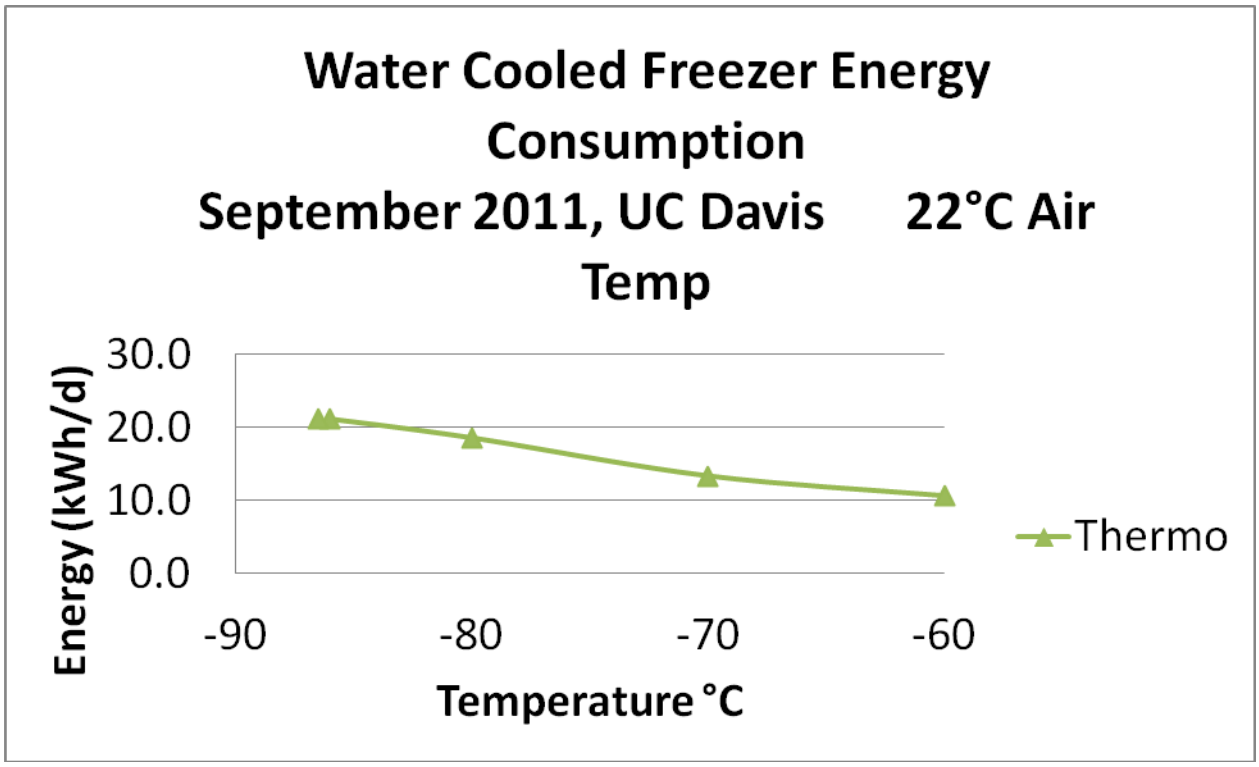


Figure 1. Energy consumption of Thermo ultra low, water cooled freezer at four set points. Second point at -86 °C is with cooling water reduced from 12 lpm to 4 lpm.

Water Consumption

The intended coolant for this freezer is re-circulated district chilled water or water from a cooling tower, so water flow is not a major energy consideration under normal circumstances. Another manufacturer uses markedly lower flow than the Forma (1/10th). This could be a factor in emergency situations where process cooling pumping may be compromised. The very low Delta T and the lack of any difference in energy consumption when water flow was reduced by 75% indicates the Thermo freezer needs additional commissioning before installation.

Appendices.

A) Complete temperature measurements and deviations.

Mean Temperature measured at Sensor

	Thermo
-60	-59.2
-70	-68.8
-80	-79.4
-86	-84.7

Mean Temperature measured in middle of freezer

	Thermo
-60	-62.1
-70	-70.0
-80	-78.5
-86	-82.3

Sensor °C - Middle °C

	Thermo
-60	2.9
-70	1.2
-80	-0.9
-86	-2.5

Cabinet uniformity was best at -80 degrees in an empty freezer, and at coldest temperatures the bottom of the freezer was colder than the middle.

Temporal Range (Max-Min)

	Thermo
-60	2.0
-70	1.8
-80	1.6
-86	3.4

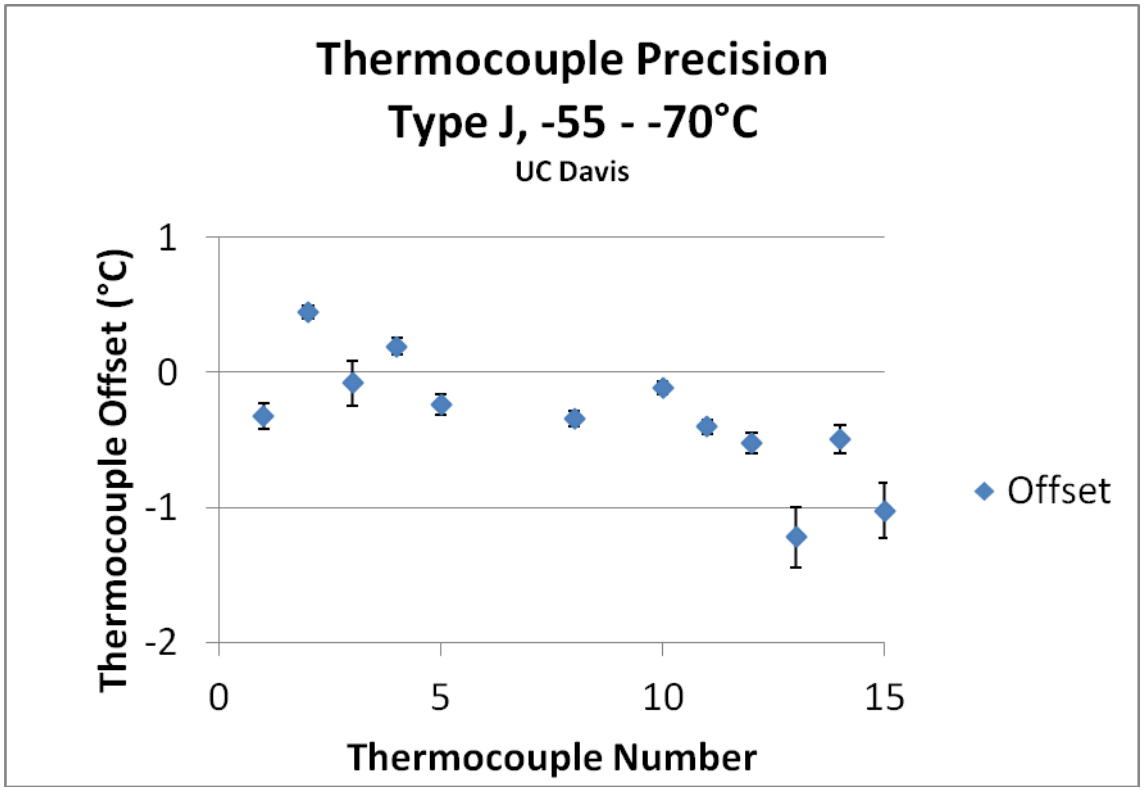
Temporal uniformity varied about 2 degrees during duty cycles.

Sensor °C -Set Pt

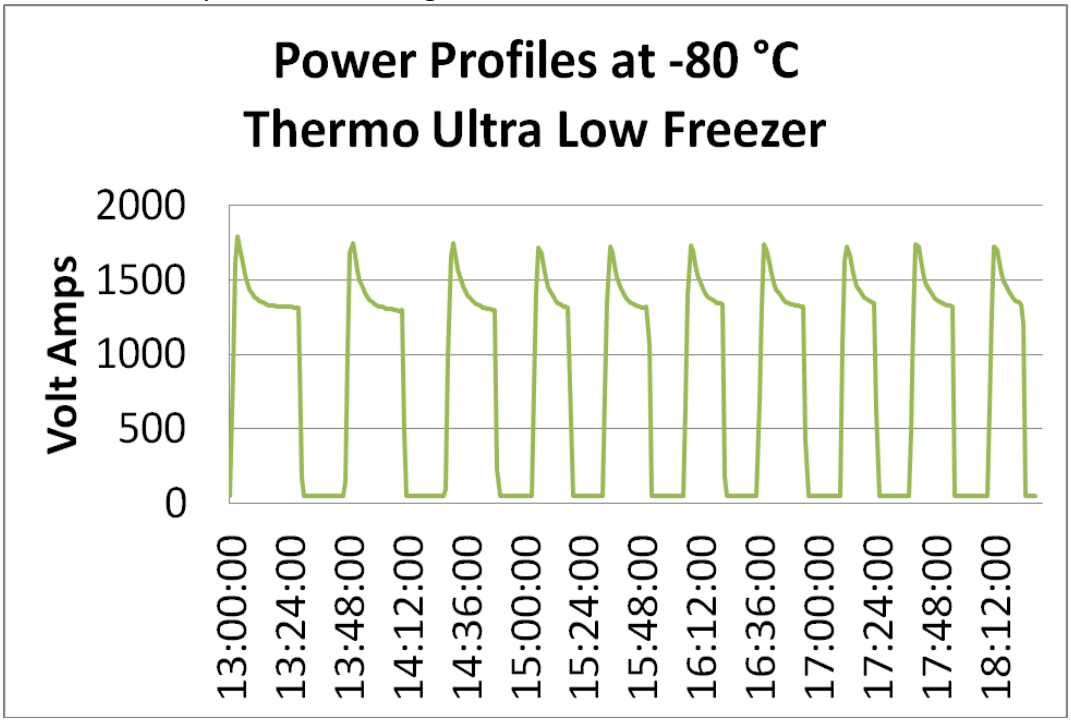
	Thermo
-60	0.8
-70	1.2
-80	0.6
-86	1.3

Temperature measured at the installed sensor was about 1.0 degree warmer than the set point.

B) Thermocouple Precision measured in methanol and dry ice bath. The thermocouples were generally within 0.5 °C, though two were a degree or more from a mean of four TC's. Offsets were applied to each thermocouple's data.



C) Thermo Power profiles at -80 degrees Celsius.



D) Example data at -80 degrees Celsius logged by the Elite Pro logger at -80 °C set point.

Record Date	Record End Time	Chan 3 Avg. Volt	Chan 3 Avg. Amp	Chan 3 Avg. KW	Chan 3 Avg. PF
8/26/2011	18:00:00	206.1	0.27	0.033	0.59
8/26/2011	18:05:00	205.1	5.99	1.17	0.95
8/26/2011	18:10:00	204.7	7.41	1.443	0.95
8/26/2011	18:15:00	204.9	6.76	1.303	0.94
8/26/2011	18:20:00	205	6.59	1.268	0.94
8/26/2011	18:25:00	206	2.22	0.413	0.91
8/26/2011	18:30:00	206.4	0.27	0.033	0.58
8/26/2011	18:35:00	206.5	0.27	0.033	0.58
8/26/2011	18:40:00	205.7	3.03	0.58	0.93
8/26/2011	18:45:00	205	7.84	1.535	0.96
8/26/2011	18:50:00	204.9	6.83	1.32	0.94
8/26/2011	18:55:00	204.5	6.6	1.268	0.94
8/26/2011	19:00:00	205	5.23	1	0.93
8/26/2011	19:05:00	206.4	0.27	0.033	0.59
8/26/2011	19:10:00	206.4	0.27	0.033	0.58
8/26/2011	19:15:00	206.1	0.28	0.033	0.58
8/26/2011	19:20:00	204.6	6.08	1.187	0.96
8/26/2011	19:25:00	204.4	7.28	1.415	0.95
8/26/2011	19:30:00	204.8	6.71	1.292	0.94
8/26/2011	19:35:00	204.5	6.55	1.258	0.94
8/26/2011	19:40:00	205.3	1.52	0.276	0.89
8/26/2011	19:45:00	205.4	0.27	0.033	0.59
8/26/2011	19:50:00	205.2	0.27	0.033	0.58
8/26/2011	19:55:00	204.7	1.84	0.342	0.91
8/26/2011	20:00:00	203.3	8	1.561	0.96
8/26/2011	20:05:00	203.1	6.86	1.322	0.95
8/26/2011	20:10:00	203.3	6.55	1.258	0.94
8/26/2011	20:15:00	203.4	5.87	1.123	0.94
8/26/2011	20:20:00	204.5	0.28	0.033	0.57
8/26/2011	20:25:00	204.6	0.28	0.033	0.57
8/26/2011	20:30:00	204.7	0.28	0.033	0.57
8/26/2011	20:35:00	204.3	2.73	0.519	0.93
8/26/2011	20:40:00	203.1	7.89	1.538	0.96
8/26/2011	20:45:00	203.3	6.8	1.311	0.95
8/26/2011	20:50:00	203	6.54	1.255	0.94
8/26/2011	20:55:00	203.4	5.18	0.989	0.94
8/26/2011	21:00:00	204.4	0.28	0.032	0.57